NATIONAL BUREAU OF STANDARDS

LYMAN J. BRIGGS - DIRECTOR

LIQUID DENSITIES OF ELEVEN HYDROCARBONS
Found in Commercial C_4 Mixtures

Compiled by C. S. Cragoe, Senior Physicist

LETTER CIRCULAR LC-736

CSC:RMS
III-3

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
Washington

Letter
Circular
LC-736

(November 23, 1943)

LIQUID DENSITIES OF ELEVEN HYDROCARBONS
Found in Commercial C_4 Mixtures

CONTENTS

Page

1. Introduction 2
2. Experimental basis of tables 2
3. Comparison of results of various observers with the tables 5
4. Equations used to calculate tables 7
5. Equations in reduced units and critical data 7
6. Vapor density and vapor pressure 8
7. Compressibility and pressure change with temperature at constant density 11
8. Units and constants. 12
9. Acknowledgment 12
10. References containing data on liquid densities 13

Table 1. Density in grams per milliliter 14

Table 2. Density in pounds per gallon. 18

Table 3. Volume at 60°F occupied by unit volume at temperature indicated. 22

1. Introduction

In July 1943, the Rubber Reserve Company requested the National Bureau of Standards to undertake the preparation of a standard table of liquid densities of six C_4 hydrocarbons, occurring in feed stocks for 1,3-butadiene manufacture, for use in weight and volume conversions.

On August 10, 1943, a conference on the subject of C_4 hydrocarbon, liquid densities was held in Washington, D.C. under the auspices of the Rubber Reserve Company. The attendance at this conference included representatives from the following organizations: (1) Rubber Reserve Company; (2) Petroleum Administration for War; (3) Technical Advisory Committee of Petroleum Industrial War Council; (4) National Bureau of Standards; (5) Petroleum Refining Laboratory, Pennsylvania State College; (6) Natural Gasoline Association of America; (7) Phillips Petroleum Company; (8) E. I. du Pont de Nemours & Company; and (9) M. W. Kellogg Company.

At this conference it was agreed: (1) to include two C_3 hydrocarbons, propane and propene, and two C_5 hydrocarbons, n-pentane and iso-pentane since these are usually present to a minor extent in the C_4 fraction; (2) to calculate densities from equations, assuming that the sum of liquid and vapor densities at saturation is a linear function of temperature; (3) to prepare three separate tables in different units, namely, grams per milliliter, pounds per gallon, and density ratios relative to the density at 60°F.; and (4) to cover the temperature range -50° to 140°F., tabulating values at every 1°F from 0° to 120°F and every 2°F outside this interval.

2. Experimental Basis of Tables

The values of density given in these tables are based largely on recent extensive measurements from three different sources, namely, Natural Gasoline Association of America(1); Royal Dutch-Shell Laboratory, Amsterdam(2); and Petroleum Refining Laboratory, Pennsylvania State College(3).* A comparison of densities in g/ml (reported values minus tabulated values) x 10^4 is given below. Thus, the numbers given indicate differences in the fourth decimal place between two values of density in g/ml. For example, for n-butane at 60°F, the N.G.A.A. reported 0.5840, these tables give 0.5838, and the difference is +0.0002 or $+2 \times 10^{-4}$.

---

*References (1), (2), (3) etc. are assembled in Section 10.

Temp. °F	Propene	Propane	Butane n-	Butane iso-	1-butene	n-pentane

Natural Gasoline Association of America (1)

Temp. °F	Propene	Propane	Butane n-	Butane iso-	1-butene	n-pentane
140	---	+44	-1	+1	---	-2
120	---	+21	+1	+3	---	+1
100	---	+6	-1	-1	---	-1
80	---	+5	-2	+3	---	-2
60	+2	+1	+2	0	-5	-2
40	+2	+4	0	-1	-7	-3
20	+2	+6	+2	+4	-8	-2
0	+4	+3	+1	+4	-8	-4

Temperature Royal Dutch-Shell Laboratory, Amsterdam (2)

Temperature °F	°C	Propane	Butane n-	Butane iso-
122	50	+4	-5	+3
113	45	+6	-6	+4
104	40	+2	-8	+4
95	35	+4	-8	+3
86	30	+1	-7	+3
77	25	+1	-7	+3
68	20	-1	-8	+3
60	15.56	+1	-8	+4
50	10	-2	-12	+3

Petroleum Refining Laboratory, Pennsylvania State College (3)

°F	°C	Propane	Butane n-	Butane iso-	Butene 1-	Butene cis-2	Butene trans-2	Butene iso-	1,3-butadiene
68	20	---	-1	0	+1	0	0	0	-5
50	10	---	-2	-4	+1	+1	0	-1	-5
32	0	---	-1	-5	0	0	+1	0	-6
14	-10	---	-1	-4	0	-1	+1	-1	-4
-4	-20	---	-2	-2	+1	-1	+2	-1	-3
-22	-30	---	0	0	+2	-1	+1	-1	-1
-40	-40	---	0	-1	+3	-2	+2	+1	+1
-58	-50	---	-3	-1	+2	-2	+1	-2	0
-76	-60	---	-3	-5	+1	-2	+1	-3	0

The tabulated values for the butenes are based largely on measurements from one laboratory (3) which are in good agreement with measurements at 32°F from another source (*) as shown below.

Butene 1-	Butene cis-2	Butene trans-2	Butene iso-	Source of Data in g/ml at 32°F
0.6183	(interpolated value)			(1)
.6190	0.6444	0.6270	0.6180	(3)
.6188	.6448	.6269	.6181	(*)
.6189	.6444	.6270	.6180	These Tables

(*) Private communication from G. Egloff, Universal Oil Products Co., which stated that samples were obtained from G. B. Kistiakowsky and co-workers (J. Am. Chem. Soc. 57, 876, 1935)

The tabulated values for n-pentane and iso-pentane are based in part on the measurements of Sidney Young and of Jean Timmermans. The agreement with the tables is indicated by the following:

Measurements		Average Difference, g/ml		Observer
No.	Range	n-pentane	iso-pentane	
9	-49 to +59°F	±0.0004	±0.0003	Timmermans (4)
4	86 to 140°F	±0.0001	±0.0003	Young (5)

The tabulated values for 1,3-butadiene are based in part on unpublished measurements by (a) the Phillips Petroleum Company, Bartlesville, Okla., (b) the Shell Development Company, Emeryville, Calif. and (c) the National Bureau of Standards.

Van der Vet of the Royal Dutch-Shell Laboratory (2) measured the density of two samples which "analytical rectifications showed --- consisted of":

Sample	n-butane	iso-butane	
1	96.6	3.4	mol %
2	9.6	90.4	mol %

The values reported for 100% of each component were calculated from the measurements using these compositions and assuming addivity of volumes. Van der Vet states that "A highly purified product was used for the determinations with propane in which, upon sampling the gas phase, no ethane could be detected, and upon sampling the residue obtained by evaporating the liquid to 10% by weight of residue, no butane could be detected. From this it was concluded that the purity of the product amounted to at least 99.5 mol %". Since the results obtained deviated considerably from values in the literature, the correctness of the result was especially checked by making duplicate determinations at 25° and 35°C with a different picnometer, different balance, and different weights. "The results showed a disparity of no more than 0.05%."

The Natural Gasoline Association of America (1) and Van der Vet (2) employed the same general method which used a lower metal cylinder, in liters 4.5 (1) and 1.3 (2), immersed in a bath, with a short connection including a valve extending above the bath to a smaller upper cylinder, partially filled with liquid and maintained at a higher temperature. By changing the temperature of the upper cylinder, Van der Vet (2) measured the isothermal compressibility of the liquid (results quoted in Section 7) and extrapolated observed densities under compression to obtain the density under saturation pressure. In the N.G.A.A. (1) measurements below room temperature, the upper cylinder was apparently unheated, while for measurements at 80°, 100°, 120° and 140°F the upper cylinder was heated externally "to keep its temperature 10° to 15°F higher than the bath temperature", and no corrections were applied for compressibility. Such corrections are large for propane as shown in the following illustration which assumes that differences ($D_0 - D_1$) between observed and tabulated values are entirely due to compressibility and leads to reasonable values for the temperature of the upper cylinder, when some allowance is made for other sources of error.

t_1, lower cylinder °F	$D_0 - D_1$ g/ml	$\frac{D_0 - D_1}{p_2 - p_1}$ $\frac{g/ml}{atm}$	$p_2 - p_1$ atm	$t_2 - t_1$ °F	t_2, upper cylinder °F
140	.0044	.00097*	4.5	18	158
120	.0021	.00061	3.4	16	136
100	.0006	.00043	1.4	8	108
80	.0005	.00033	1.5	10	90
60	.0001	.00027	0.4	3	63
40	.0004	.00023	1.7	18	58
20	.0006	.00020	3.0	36	56
0	.0003	.00018	1.7	28	28

D_0 = density observed at t_1 under pressure p_2

D_1 = density tabulated at t_1 under pressure p_1 (saturation)

$p_2 - p_1$ = amount of compression (column 2 divided by column 3)

$t_2 - t_1$ = temp. corresponding to change in vapor pressure, $p_2 - p_1$

*Values in this column were obtained from measurements of Van der Vet, assuming $(dD/dp)_t$ a linear function of $1/(t_c - t)^2$ (t_c = critical temperature). The N.G.A.A. measurements on propane are in good accord with these tables.

3. Comparison of Results of Various Observers with the Tables.

Dana and co-workers (6) estimated the accuracy of their results on liquid densities as 0.5%. The variation with temperature, over the observed range, 32° to 133°F, is in good agreement with the tables but the absolute values differ systematically as follows:

	Propane	n-butane	iso-butane
No. of observations	12	8	8
Observed - tables, % avg.	+0.43	-0.27	+0.22
Observed - tables, g/ml avg.	+0.0020	-0.0015	+0.0012

The above statement also applies to the extensive measurements obtained in the Physical Chemistry Laboratory of McGill University, Montreal, Canada, as follows:

Hydrocarbon	No. of Obs.	Temp. Range °F	Obs.-Tables Average g/ml	%	Reference
Propane	6	-50 to -12	+0.0018	+0.31	Maass & Wright (7)
Propene	7	-55 to +66	+ .0014	+ .25	Maass & Wright (7)
Propene	8	+68 to +139	+ .0011	+ .24	Pall & Maass (8)
n-butane	19	-30 to +90	± .0003	± .05	Coffin & Maass (9)
iso-butane	19	-18 to +78	+ .0020	+ .34	Coffin & Maass (9)
1-butene	33	-50 to +50	- .0012	- .20	Coffin & Maass (9)
2-butene*	26	-44 to +64	+ .0040*	+ .62*	Coffin & Maass (9)
iso-butene	25	-58 to +53	+ .0010	+ .16	Coffin & Maass (10)

* A mixture of cis and trans-2-butene. The observed densities are compared with tabulated values for trans-2-butane.

The results obtained at the California Institute of Technology, compare with the tables, as follows:

Temp.	Obs. - tables		
°F	g/ml	%	Reference
	Propane		
69.4	+0.0034	+0.7	
93.8	+ .0031	+0.7	Sage, Schaafsma & Lacey (11)
113.8	+ .0039	+0.9	
122.4	+ .0049	+1.1	
130.6	+ .0061	+1.4	
138.1	+ .0072	+1.7	
	n-butane		
70	+ .0041	+ .71	
100	+ .0030	+ .54	Sage, Webster & Lacey (12)
130	+ .0037	+ .69	
	iso-butane		
70	+ .0037	+ .67	
100	+ .0027	+ .50	Sage & Lacey (13)
130	+ .0020	+ .39	

Comparison with the results of other observers is as follows:

	Propane		
86	+ .0011	+0.2	
104	+ .0039	+0.8	Deschner & Brown (14)
122	+ .0057	+1.3	
140	+ .0070	+1.6	
	Propene		
32	+ .0446	+8.2	
77	+ .0317	+6.3	Vaughan & Graves (15)
122	+ .0221	+4.8	
	n-butane		
32	+ .0003	+ .05	
70	+ .0003	+ .05	Kay (16)
100	+ .0005	+ .09	
130	+ .0008	+ .15	
	n-pentane		
32	- .0002	- .03	Chavanne & Simon (17)
59	- .0003	- .05	Calingaert (18)
-22	- .0011	- .16	Dornte & Smyth (19)
14	- .0009	- .14	Dornte & Smyth (19)
50	- .0001	- .02	Dornte & Smyth (19)
68	+ .0001	+ .02	Dornte & Smyth (19)
86	.0000	.00	Dornte & Smyth (19)
	iso-pentane		
32	.0000	.00	Chavanne & Simon (17)
32	.0000	.00	Timmermans & Martin (20)
59	.0000	.00	Timmermans & Martin (20)
59	- .0002	- .03	Calingaert (18)
	1,3-butadiene		
21.2	- .0022	-0.34	Prevost (21)
68	+ .0001	+ .02	I.G. Farb. (22)
50	+ .0003	+ .05	"
32	+ .0004	+ .06	"
14	+ .0003	+ .05	"
-4	- .0005	- .07	"

4. Equations Used to Calculate Tables.

The values of liquid density at saturation reported in these tables were calculated from equations of the form

$$D\ (\text{liquid}) + D\ (\text{vapor}) = A - Bt \qquad (1)$$

where D = density in g/ml and t = temperature in °F. The constants A and B, chosen to fit the experimental data used as a basis for the tables (See Section 2), are as follows:

Hydrocarbon	A	B
propane	0.55780	0.000575
propene	.57770	.000625
n-butane	.62095	.000542
iso-butane	.~~62065~~.60265	.000553
1-butene	.64110	.000585
cis-2-butene	.66520	.000580
trans-2-butene	.64750	.000565
iso-butene	.64000	.000580
1,3-butadiene	.66715	.000593
n-pentane	.66285	.000513
iso-pentane	.65690	.000513

5. Equations in Reduced Units and Critical Data

Equation (1) gives at the critical temperature, t_c.

$$D\ (\text{liquid}) + D\ (\text{vapor}) = 2D_c\ (\text{critical density}) = A - Bt_c \qquad (2)$$

Equation (1) may be written in reduced units in the form:

$$\frac{D\ (\text{liquid}) + D\ (\text{vapor})}{2\ D_c\ (\text{critical})} = 1 + C\ (1 - T/T_c) \qquad (3)$$

where $T = t°F + 459.7$ and $C = BT_c/2D_c$

Equations (1) (2) and (3) are expressions of the so-called "Law of the Rectilinear Diameter" usually credited to Cailletet and Mathias (Compt. rend. 102, 1202, 1886). This law, like the ideal solution laws, fits the facts within experimental errors in some cases but not in others. A fairly general rule seems to be: (1) when C is less than unity, the law is obeyed, (the mean diameter is straight); (2) when C is greater than unity, the law fails (the mean diameter is curved). This rule is not confined to hydrocarbons but applies to the elements and to all single-component liquids for which accurate data are available. In some cases where the rectilinear diameter law holds above the normal boiling point, there is some indication of deviations exceeding experimental errors as the freezing point is approached, although such deviations might be attributable to impurities (dissolved air, for example).

In the case of the 11 hydrocarbons considered here, the most accurate data available indicate that the law is obeyed over the temperature range covered by the measurements within the accuracy estimated by the observers (usually less than 0.1%). Extrapolating the mean diameter to the critical temperature gives a value for the critical density, D_c, which is probably more reliable than can be obtained by any other method. The values of D_c calculated in this manner are given below. An error of 1°F in t_c corresponds to about 0.1% in D_c, while a systematic error in the experimental data at the lower temperatures yielding an erroneous value for the slope, B in eq (1) or C in eq (3), might correspond to more than 1% in D_c. Some evidence of the consistency of the data is supplied by the reasonably consistent values obtained for the dimentionless quantities C and $P_cV_c/RT_c = MP_c/D_cRT_c$ (where M = molecular weight). Further evidence is supplied by the fact that equations (1), with the constants A and B determined from data over the range -50° to 140°F, yield values of D_c which are consistent with isothermal data in the critical region.

Hydrocarbon	t_c °F	P_c atm	D_c g/ml	C	$\frac{P_cV_c}{RT_c}$
Propane	206.2a	42.0a	0.2196[i]	0.871	0.279
Propene	196.5b	45.5b	.2277	.901	.280
n-butane	305.6c	37.5c	.2277	.911	.274
iso-butane	272.2d 273.2	~~36.9d~~ 36.1	~~.2348~~ .2258	~~.863~~ .898	~~.273~~ .278
1-butene	291.0e	39.2*	.2354	.933	.273
cis-2-butene	320 *	41.5*	.2398	.943	.273
trans-2-butene	311 *	40.5*	.2359	.923	.274
iso-butene	292.5f	39.5f	.2352	.927	.275
1,3-butadiene	305.6g	42.7g	.2430	.934	.272
n-pentane	387.0h	33.0h	.2322	.935	.266
iso-pentane	370.0h	32.9h	.2336	.911	.269

*Estimated value

a J. A. Beattie, N. Poffenberger and C. Hadlock, J. Chem. Phys. 3,96,1935

b W. E. Vaughan and N. R. Graves, Ind. Eng. Chem. 32, 1252, 1940

c J. A. Beattie, G. L. Simard and G. J. Su, J. Am. Chem. Soc. 61, 24,1939; also Kay, reference (16)

d Natural Gasoline Association of America, "Physical Constants of Paraffin Hydrocarbons," ~~August, 1941~~ May 1942.

e C. C. Coffin and O. Maass, J. Amer. Chem. Soc. 50, 1427, 1928

f J. A. Beattie, H. G. Ingersoll and W. H. Strockmayer, J. Am. Chem. Soc. 64, 546, 1942

g National Bureau of Standards, unpublished measurements

h S. Young, Sci. Proc. Roy. Dublin Soc. 12, 374, 1910

i Values in this column were calculated from eq (2). They are consistent with measurements in the critical region. See "An equation for the isotherms of pure substances at their critical temperatures" by C. H. Meyers, J. Research Nat. Bur. Standards 29, 157, 1942 (Research Paper 1493).

6. Vapor Density and Vapor Pressure

Values of the density of the saturated vapor are not given for all of the liquids in these tables but approximate values may be obtained easily by using eq (1) in the form

D(vapor in g/ml) = A - Bt(°F) - D (liquid, tabulated value in g/ml)

For example, substituting the appropriate values for 1,3-butadiene at 60°F gives

$$D(\text{vapor}) = 0.66715 - 0.03558 - 0.6266 = 0.0050 \text{ g/ml}$$

For use in calculating the tables, vapor densities were calculated from data on vapor pressure, taking into account deviations from the ideal gas law by means of the relation

$$\frac{PV}{RT}\text{ (vapor)} = 1 - \frac{(P/eP_c)^n}{1 - \frac{PV}{RT}\text{ (liquid)}}$$

where V = vol/mole, P_c = critical pressure (values in section 5 were used). e = 2.718; n = 0.70 which has been shown to agree well with existing data on many substances (See C. H. Meyers, Bur. Standards J. Research 11, 691, 1933, RP 616).

Vapor pressure measurements available in the literature are discordant on some of these hydrocarbons, probably due to differences in purity, and no measurements were found above the normal boiling point for some of the butenes. Values of vapor pressure, given below, appear to be sufficiently reliable for the purposes of calculating these tables but may be inadequate for some other purposes. These values were obtained from available data by plotting log p + 4.343 T_b/T versus T (T_b = T at normal boiling point) which brings the curves together near the normal boiling point, making extrapolations easier and permits reading from the curves to a fraction of one percent.

Temp. °F	Propane	Propene	Butane		Butene				1,3 Butadiene	Pentane	
			n-	iso-	1-	cis-2	trans -2	iso-		n-	iso-
(Vapor pressure in atmospheres used to calculate tables)											
140	20.87	24.67	6.29	8.54	7.56	5.68	6.10	7.66	7.21	2.096	2.705
120	16.47	19.58	4.77	6.56	5.60	4.26	4.59	5.67	5.45	1.510	1.965
100	12.85	15.35	3.54	4.94	4.25	3.12	3.37	4.30	4.03	1.059	1.392
80	9.82	11.82	2.56	3.63	3.08	2.23	2.42	3.12	2.91	0.719	0.959
60	7.35	8.91	1.79	2.60	2.18	1.54	1.69	2.21	2.05	.471	.640
40	5.37	6.56	1.21	1.81	1.50	1.03	1.14	1.53	1.39	.295	.412
20	3.82	4.70	0.79	1.21	0.99	0.66	0.74	1.01	.92	.177	.254
0	2.62	3.26	.50	0.78	.63	.41	.46	0.64	.58	.100	.148
-20	1.74	2.18	.29	.48	.38	.24	.27	.39	.35	.054	.082
-40	1.10	1.39	.17	.28	.22	.13	.15	.22	.20	.027	.043
References: (numbers refer to references given in Section 10)											
	b,c,d,6 7,11,14	a,d 7,15	f,3,9 12,16	g,3 9,13	a 3,9	a 3	a 3	a,h,m 3,10	k,m 3	i 5	j 5

a Lamb and Roper, J. Am. Chem. Soc. 62, 806, 1940
b Kemp and Egan, J. Am. Chem. Soc. 60, 1521, 1938
c Beattie, Poffenberger, and Hadlock, J. Chem. Phys. 3, 96, 1935
d Francis and Robbins, J. Am. Chem. Soc., 55, 4339, 1933
e Powell and Giaugue, J. Am. Chem. Soc., 61, 2366, 1939
f Aston and Messerly, J. Am. Chem. Soc., 62, 1917, 1940
g Aston, Kennedy and Schumann, J. Am. Chem. Soc., 62, 2059, 1940
h Beattie, Ingersoll and Strockmayer, J. Am. Chem. Soc. 64, 546, 1942
i Messerly and Kennedy, J. Am. Chem. Soc. 62, 2988, 1940
j Schumann, Aston and Sagenkahn, J. Am. Chem. Soc., 64, 1039, 1942
k National Bureau of Standards (unpublished measurements)
m Moore and Kanep, Trans. Experimental-Research Laboratory "Chemgas", Materials on Cracking and Chemical Treatment of Cracking Products, Vol III, p. 147, 1936, Leningrad.

At atmospheric temperatures during summer, the vapor densities of many of the C4-hydrocarbons exceed one percent of the liquid densities and it may be desired to take into account the amounts remaining in partially empty containers. The following values, computed as outlined above, may be useful in practical applications, since pressure is easier to measure than the temperature of vapors, and vapor density varies linearly with pressure more closely than with temperature.

Gage Pressure lb/sq.in.	Vapor Density n-Butane lb/gal	Vapor Density 1,3-Butadiene lb/gal
90	0.1475	0.1375
88	.1447	.1349
86	.1419	.1323
84	.1391	.1297
82	.1363	.1271
80	.1334	.1245
78	.1306	.1219
76	.1278	.1194
74	.1250	.1168
72	.1222	.1142
70	.1194	.1116
68	.1166	.1090
66	.1138	.1064
64	.1110	.1039
62	.1082	.1013
60	.1054	.0987
58	.1026	.0961
56	.0998	.0935
54	.0971	.0910
52	.0943	.0884
50	.0916	.0859
48	.0888	.0833
46	.0861	.0807
44	.0834	.0782
42	.0806	.0756
40	.0779	.0731
38	.0752	.0705
36	.0724	.0679
34	.0697	.0654
32	.0670	.0628
30	0.0642	0.0603
28	.0615	.0577
26	.0588	.0551
24	.0560	.0526
22	.0533	.0500
20	.0506	.0474
18	.0478	.0448
16	.0450	.0422
14	.0423	.0396
12	.0395	.0370
10	.0367	.0344
8	.0339	.0318
6	.0311	.0292
4	.0283	.0265
2	.0255	.0239
0	.0226	.0212
Inches Hg below 1 atm.		
0	.0226	.0212
2	.0211	.0199
4	.0197	.0186
6	.0183	.0172
8	.0169	.0159
10	.0154	.0145
12	.0140	.0132
14	.0125	.0118
16	.0111	.0104
18	.0096	.0090
20	.0081	.0076

At the same pressure, the vapor densities of the butenes are intermediate between the above values for n-butane and 1,3-butadiene, and the vapor density of iso-butane is about 4 percent greater than the value given for n-butane.

7. Compressibility and Pressure Change with Temperature at Constant Density

For a single phase, the density, D, is a function only of the temperature, t, and pressure, p, expressed by the equation

$$dD = (dD/dt)_p \, dt + (dD/dp)_t \, dp$$

Applying this equation to the liquid phase at or very close to the saturation limit, designated by the subscript, s, gives the relation

$$(dD/dt)_s = (dD/dt)_p + (dD/dp)_t \, (dp/dt)_s$$

and also

$$(dp/dt)_D = -(dD/dt)_p \, (dp/dD)_t = (dp/dt)_s - (dp/dD)_t \, (dD/dt)_s$$

Values for the various terms in this equation are given below for propane, n-butane and iso-butane. The values for compressibility, $-(1/V)(dV/dp)_t$, are quoted from measurements reported by Van Der Vet (2). These values were multiplied by the density and by the factor 1.033 (to convert pressure units from Kg/cm^2 to atmospheres) which give the tabulated values for $(dD/dp)_t$. Values for $(dD/dt)_s$ were obtained from the data used as a basis for these tables of liquid density at saturation. Values for $(dp/dt)_s$ were obtained from available vapor pressure data and values for $(dp/dt)_D$ were calculated using the above equation.

Temperature °F	Temperature °C	$-\frac{(dV/dp)_t}{V}$ x 10^4 $(kg/cm^2)^{-1}$	D g/ml	$(dD/dp)_t$ x 10^4 (g/ml)/atm	$-(dD/dt)_s$ x 10^4 (g/ml)/°F	$-\frac{(dD/dt)_s}{(dD/dp)_t}$ atm/°F	$(dp/dt)_s$ atm/°F	$(dp/dt)_D$ atm/°F
				Propane				
50	10	4.40	0.515	2.34	7.85	3.35	0.10	3.4
68	20	5.60	.500	2.89	8.40	2.91	.12	3.0
86	30	7.20	.485	3.61	9.10	2.52	.15	2.7
104	40	9.40	.468	4.54	10.0	2.20	.18	2.4
122	50	13.70	.449	6.35	11.2	1.76	.21	2.0
				n-butane				
50	10	2.25	0.590	1.37	6.1	4.45	0.03	4.5
68	20	2.75	.579	1.64	6.3	3.84	.04	3.9
86	30	3.25	.567	1.90	6.5	3.42	.05	3.5
104	40	3.90	.555	2.24	6.8	3.04	.06	3.1
122	50	4.60	.543	2.58	7.1	2.75	.07	2.8
				iso-butane				
50	10	2.80	0.569	1.65	6.5	3.94	0.04	4.0
68	20	3.40	.557	1.96	6.8	3.47	.05	3.5
86	30	4.05	.545	2.28	7.1	3.11	.06	3.2
104	40	4.85	.532	2.67	7.4	2.77	.08	2.9
122	50	5.90	.518	3.16	7.8	2.47	.09	2.6

Problem: If a container is filled completely with liquid C4-hydrocarbons at 50°F and the temperature rises to 75°F the next day, what would be the rise in pressure?

Assumptions: (a) Neglect the small change in volume of the container with temperature and pressure; (b) assume an approximate value $(dp/dt)_D = 4$ atm/°F.

Answer: 4 (atm/°F) x 25 (°F, temp. rise) = 100 atm (pressure rise) or roughly 1500 lbs/in^2.

Large containers are not constructed to withstand such high pressures, which emphasizes the need for precautions against overcharging and for pressure relief devices to protect against violent ruptures.

8. Units and Constants

Mass. All units of weight used here are weights in vacuo (mass) and not apparent weight in air. The fundamental unit of mass used is the kilogram which is related to the pound approximately as follows:

$$1 \text{ pound} = 0.4535924 \text{ Kilograms}$$

Volume. One unit of liquid volume is the liter, defined as the volume occupied by 1 kilogram of water at its maximum density (4°C or 39.2°F). This unit is related to the cube of a unit of length as follows:

$$1 \text{ liter} = 1000.027 \text{ cm}^3$$

From the present legal definition of length,

$$1 \text{ cm} = 0.3937 \text{ in.}$$

hence

$$1 \text{ liter} = 1000.027 \times (0.3937)^3 = 61.0250 \text{ in}^3$$

and

$$1 \text{ gallon} = 231 \text{ in}^3 = 231/61.0250 = 3.785332 \text{ liters}$$

Density. Mass per unit volume is the universal definition of density. Using the above factors for mass and volume,

$$1 \text{ lb/gal} = 453.5924/3785.332 = 0.1198290 \text{ g/ml}$$

and

$$1 \text{ g/ml} = 3785.332/453.5924 = 8.34523 \text{ lb/gal}$$

Values of density in g/ml were calculated from the equations to 5 figures and rounded to 4 figures in table 1. The values in g/ml to 5 figures were (a) multiplied by 8.34523 to convert to values in lb/gal given in table 2 and (b) divided by the density at 60°F in g/ml to 5 figures to yield the ratios given in table 3.

Specific gravity. Densities are frequently expressed in terms of specific gravities, defined by

$$\text{Specific gravity} = \frac{\text{density of liquid at } t_1\text{°F.}}{\text{density of water at } t_2\text{°F.}}$$

Any chosen variety of specific gravity may be obtained from the tabulated densities. For 1,3-butadiene, for example

$$\text{Specific gravity at } 60°/60°\text{F} = 0.6266/0.99904 = 0.6272$$

9. Acknowledgment

Financial assistance in the work involved in the preparation of these tables was provided by the Rubber Reserve Company.

10. References containing Data on Liquid Densities

1. "Densities of Liquefied Petroleum Gases", Technical Committee, Natural Gasoline Association of America, J. Am. Chem. Soc. 34, 1240, 1942; Proceedings 21st Annual Convention, NGAA, May 1942, p. 11.

2. "Density, Compressibility, Expansion of Light Hydrocarbons and of Light Hydrocarbon Blends", A. P. Van der Vet, Royal Dutch-Shell Laboratory, Amsterdam, 2nd World Petroleum Congress, Paris 1937, Vol 2, Sec. 2, p. ~~55~~ 515

3. "Some Physical Constants of Seven Four-Carbon-Atom Hydrocarbons and Neopentane" Petroleum Refining Laboratory, Pennsylvania State College, August 1941.

4. J. Timmermans, Sci. Proc. Roy. Dublin Soc. 13, 310, 1912

5. S. Young, Sci. Proc. Roy Dublin Soc. 12, 374, 1910

6. L. I. Dana, A. C. Jenkins, J. N. Burdick and R. C. Timm, Refrig. Eng. 12, 387, 1926

7. O. Maass and C. H. Wright, J. Amer. Chem. Soc. 43, 1098, 1921

8. D. P. Pall and O. Maass, Can. J. Research 14B, 96, 1936

9. C. C. Coffin and O. Maass, J. Amer. Chem. Soc. 50, 1427, 1928

10. C. C. Coffin and O. Maass, Trans. Roy. Soc. (Canada) 21, 33, 1927

11. B. H. Sage, J. G. Schaafsma and W. N. Lacey, Ind. Eng. Chem. 26, 1218, 1934

12. B. H. Sage, D. C. Webster and W. N. Lacey, Ind. Eng. Chem. 29, 1188, 1937

13. B. H. Sage and W. N. Lacey, Ind. Eng. Chem. 30, 673, 1938

14. W. W. Deschner and G. G. Brown, Ind. Eng. Chem. 32, 836, 1940

15. W. E. Vaughan and N. R. Graves, Ind. Eng. Chem. 32, 1252, 1940

16. W. B. Kay, Ind. Eng. Chem. 32, 358, 1940

17. G. Chavanne and L. J. Simon, Compt. rend. 168, 1324, 1919

18. G. Calingaert, J. Am. Chem. Soc. 45, 130, 1923

19. R. W. Dornte and C. P. Smyth, J. Am. Chem. Soc. 52, 3546, 1930

20. J. Timmermans and F. Martin, J. Chem. Phys. 23, 733, 1926

21. C. Prevost, Compt. rend. 186, 1209, 1928

22. I. G. Farbenindustrie, Ludwigshafen 1929, Landolt-Bornstein Physical-Chemical Tables, 5th edition, 2nd supplement, Part I, p. 207

Table 1. Density in grams per milliliter

Temp. °F	Propane	Propene*	Butane		Butene*				1,3-Butadiene	Pentane	
			n-	iso-	1-	cis-2	trans -2	iso-		n-	iso-
-50	0.5845	0.6064	0.6477	0.6296	0.6698	0.6939	0.6754	0.6685	0.6964	0.6884	0.6824
-48	.5832	.6050	.6466	.6285	.6686	.6927	.6743	.6673	.6952	.6874	.6814
-46	.5820	.6036	.6454	.6273	.6674	.6915	.6731	.6661	.6940	.6864	.6804
-44	.5807	.6023	.6443	.6262	.6662	.6904	.6720	.6649	.6928	.6853	.6793
-42	.5794	.6009	.6432	.6251	.6650	.6892	.6708	.6637	.6915	.6843	.6783
-40	.5782	.5995	.6421	.6239	.6638	.6880	.6696	.6625	.6903	.6833	.6773
-38	.5769	.5981	.6410	.6228	.6626	.6868	.6685	.6613	.6891	.6822	.6762
-36	.5756	.5967	.6399	.6216	.6614	.6856	.6673	.6601	.6879	.6812	.6752
-34	.5744	.5953	.6388	.6204	.6602	.6845	.6662	.6589	.6866	.6802	.6742
-32	.5731	.5939	.6377	.6193	.6590	.6833	.6650	.6577	.6854	.6791	.6731
-30	.5718	.5925	.6365	.6181	.6578	.6821	.6639	.6565	.6842	.6781	.6721
-28	.5705	.5911	.6354	.6170	.6566	.6809	.6627	.6553	.6830	.6771	.6710
-26	.5692	.5897	.6343	.6158	.6554	.6797	.6615	.6541	.6818	.6760	.6700
-24	.5679	.5882	.6332	.6146	.6542	.6785	.6604	.6529	.6805	.6750	.6690
-22	.5666	.5868	.6321	.6134	.6529	.6773	.6592	.6517	.6793	.6739	.6679
-20	.5653	.5854	.6309	.6123	.6517	.6761	.6580	.6505	.6781	.6729	.6669
-18	.5640	.5839	.6298	.6111	.6505	.6749	.6569	.6493	.6768	.6719	.6658
-16	.5627	.5825	.6287	.6099	.6493	.6737	.6557	.6481	.6756	.6708	.6648
-14	.5613	.5810	.6275	.6087	.6480	.6725	.6545	.6468	.6744	.6698	.6637
-12	.5600	.5795	.6264	.6076	.6468	.6713	.6533	.6456	.6731	.6688	.6627
-10	.5587	.5781	.6253	.6064	.6456	.6701	.6521	.6444	.6719	.6677	.6616
-8	.5573	.5766	.6241	.6052	.6443	.6689	.6510	.6432	.6706	.6667	.6606
-6	.5560	.5751	.6230	.6040	.6431	.6677	.6498	.6419	.6694	.6656	.6595
-4	.5546	.5736	.6218	.6028	.6419	.6665	.6486	.6407	.6681	.6646	.6585
-2	.5532	.5721	.6207	.6016	.6406	.6653	.6474	.6395	.6669	.6636	.6574
0	.5519	.5706	.6196	.6004	.6394	.6641	.6462	.6382	.6656	.6625	.6564
1	.5512	.5699	.6190	.5998	.6387	.6635	.6456	.6376	.6650	.6620	.6559
2	.5505	.5691	.6184	.5992	.6381	.6629	.6450	.6370	.6644	.6614	.6553
3	.5498	.5683	.6178	.5986	.6375	.6623	.6444	.6364	.6637	.6609	.6548
4	.5491	.5676	.6173	.5980	.6369	.6617	.6438	.6357	.6631	.6604	.6543
5	.5484	.5668	.6167	.5974	.6362	.6610	.6433	.6351	.6625	.6599	.6537
6	.5477	.5660	.6161	.5968	.6356	.6604	.6427	.6345	.6618	.6594	.6532
7	.5470	.5653	.6155	.5962	.6350	.6598	.6421	.6339	.6612	.6588	.6527
8	.5463	.5645	.6149	.5956	.6344	.6592	.6415	.6332	.6606	.6583	.6522
9	.5456	.5637	.6144	.5950	.6337	.6586	.6409	.6326	.6600	.6578	.6516
10	.5449	.5630	.6138	.5944	.6331	.6580	.6403	.6320	.6593	.6573	.6511
11	.5442	.5622	.6132	.5937	.6325	.6574	.6397	.6314	.6587	.6567	.6506
12	.5435	.5614	.6126	.5931	.6319	.6568	.6391	.6307	.5681	.6562	.6500
13	.5428	.5606	.6120	.5925	.6312	.6562	.6385	.6301	.6574	.6557	.6495
14	.5421	.5598	.6115	.5919	.6306	.6555	.6379	.6295	.6568	.6552	.6490

*Propene also known as propylene; butene also known as butylene.

Table 1. Density in grams per milliliter (Cont'd)

Temp. °F	Propane	Propene*	Butane		Butene*				1,3-Butadiene	Pentane	
			n-	iso-	1-	cis-2	trans-2	iso-		n-	iso-
15	0.5414	0.5590	0.6109	0.5913	0.6299	0.6549	0.6373	0.6289	0.6561	0.6546	0.6485
16	.5407	.5582	.6103	.5907	.6293	.6543	.6367	.6282	.6555	.6541	.6479
17	.5400	.5575	.6097	.5901	.6287	.6537	.6361	.6276	.6549	.6536	.6474
18	.5393	.5567	.6091	.5895	.6280	.6531	.6354	.6270	.6542	.6531	.6469
19	.5385	.5559	.6085	.5888	.6274	.6525	.6348	.6263	.6536	.6525	.6463
20	.5378	.5551	.6080	.5882	.6268	.6519	.6342	.6257	.6530	.6520	.6458
21	.5371	.5543	.6074	.5876	.6261	.6512	.6336	.6251	.6523	.6515	.6453
22	.5364	.5535	.6068	.5870	.6255	.6506	.6330	.6244	.6517	.6510	.6447
23	.5356	.5527	.6062	.5864	.6248	.6500	.6324	.6238	.6510	.6504	.6442
24	.5349	.5519	.6056	.5857	.6242	.6494	.6318	.6232	.6504	.6499	.6436
25	.5342	.5510	.6050	.5851	.6236	.6488	.6312	.6225	.6497	.6494	.6431
26	.5335	.5502	.6044	.5845	.6229	.6481	.6306	.6219	.6491	.6488	.6426
27	.5327	.5494	.6038	.5839	.6223	.6475	.6300	.6212	.6484	.6483	.6420
28	.5320	.5486	.6032	.5832	.6216	.6469	.6294	.6206	.6478	.6478	.6415
29	.5312	.5478	.6026	.5826	.6210	.6463	.6287	.6200	.6471	.6472	.6410
30	.5305	.5470	.6020	.5820	.6204	.6456	.6281	.6193	.6465	.6467	.6404
31	.5298	.5462	.6014	.5813	.6197	.6450	.6275	.6187	.6459	.6462	.6399
32	.5290	.5454	.6009	.5807	.6190	.6444	.6269	.6180	.6452	.6456	.6394
33	.5283	.5445	.6003	.5801	.6184	.6438	.6263	.6174	.6446	.6451	.6388
34	.5275	.5437	.5997	.5794	.6177	.6431	.6257	.6167	.6439	.6446	.6383
35	.5268	.5429	.5991	.5788	.6171	.6425	.6251	.6161	.6432	.6441	.6377
36	.5260	.5420	.5985	.5782	.6164	.6419	.6244	.6154	.6426	.6435	.6372
37	.5253	.5412	.5979	.5775	.6158	.6412	.6238	.6148	.6419	.6430	.6367
38	.5245	.5404	.5973	.5769	.6151	.6406	.6232	.6141	.6413	.6424	.6361
39	.5237	.5395	.5967	.5763	.6145	.6400	.6226	.6135	.6406	.6419	.6356
40	.5230	.5387	.5961	.5756	.6138	.6394	.6220	.6128	.6400	.6414	.6350
41	.5222	.5379	.5955	.5750	.6132	.6387	.6213	.6122	.6393	.6408	.6345
42	.5214	.5370	.5949	.5743	.6125	.6381	.6207	.6115	.6387	.6403	.6340
43	.5207	.5362	.5942	.5737	.6119	.6375	.6201	.6109	.6380	.6398	.6334
44	.5199	.5353	.5936	.5730	.6112	.6368	.6195	.6102	.6373	.6392	.6329
45	.5191	.5345	.5930	.5724	.6105	.6362	.6189	.6096	.6367	.6387	.6323
46	.5183	.5336	.5924	.5717	.6099	.6356	.6182	.6089	.6360	.6382	.6318
47	.5176	.5328	.5918	.5711	.6092	.6349	.6176	.6082	.6353	.6376	.6312
48	.5168	.5319	.5912	.5705	.6085	.6343	.6170	.6076	.6347	.6371	.6307
49	.5160	.5310	.5906	.5698	.6079	.6336	.6163	.6069	.6340	.6366	.6301
50	.5152	.5302	.5900	.5692	.6072	.6330	.6157	.6063	.6333	.6360	.6296
51	.5144	.5293	.5894	.5685	.6066	.6324	.6151	.6056	.6327	.6355	.6291
52	.5136	.5284	.5887	.5678	.6059	.6317	.6145	.6050	.6320	.6349	.6285
53	.5128	.5275	.5881	.5672	.6052	.6311	.6138	.6043	.6313	.6344	.6280
54	.5120	.5266	.5875	.5665	.6045	.6304	.6132	.6036	.6307	.6339	.6274

*Propene also known as propylene; butene also known as butylene.

Table 1. Density in grams per milliliter (Cont'd)

Temp.			Butane		Butene*				1,3-	Pentane	
°F	Propane	Propene*	n-	iso-	1-	cis-2	trans -2	iso-	Butadiene	n-	iso-
55	0.5112	0.5258	0.5869	0.5659	0.6039	0.6298	0.6126	0.6030	0.6300	0.6333	0.6269
56	.5104	.5249	.5863	.5652	.6032	.6291	.6119	.6023	.6293	.6328	.6263
57	.5096	.5240	.5856	.5645	.6025	.6285	.6113	.6016	.6286	.6322	.6258
58	.5088	.5231	.5850	.5639	.6019	.6278	.6106	.6009	.6280	.6317	.6252
59	.5080	.5222	.5844	.5632	.6012	.6272	.6100	.6003	.6273	.6311	.6247
60	.5072	.5213	.5838	.5626	.6005	.6266	.6094	.5996	.6266	.6306	.6241
61	.5064	.5204	.5832	.5619	.5998	.6259	.6087	.5989	.6259	.6301	.6235
62	.5055	.5195	.5825	.5612	.5991	.6253	.6081	.5983	.6252	.6295	.6230
63	.5047	.5185	.5819	.5605	.5985	.6246	.6075	.5976	.6246	.6290	.6224
64	.5039	.5176	.5813	.5599	.5978	.6239	.6068	.5969	.6239	.6284	.6219
65	.5031	.5167	.5806	.5592	.5971	.6233	.6062	.5962	.6232	.6279	.6213
66	.5022	.5158	.5800	.5585	.5964	.6226	.6055	.5955	.6225	.6273	.6208
67	.5014	.5148	.5794	.5579	.5957	.6220	.6049	.5949	.6218	.6268	.6202
68	.5005	.5139	.5788	.5572	.5951	.6213	.6042	.5942	.6211	.6262	.6196
69	.4997	.5130	.5781	.5565	.5944	.6207	.6036	.5935	.6205	.6257	.6191
70	.4988	.5120	.5775	.5558	.5937	.6200	.6029	.5928	.6198	.6251	.6185
71	.4980	.5111	.5768	.5551	.5930	.6194	.6023	.5921	.6191	.6246	.6180
72	.4971	.5101	.5762	.5544	.5923	.6187	.6016	.5914	.6184	.6240	.6174
73	.4963	.5092	.5756	.5537	.5916	.6180	.6010	.5907	.6177	.6235	.6169
74	.4954	.5082	.5749	.5531	.5909	.6174	.6003	.5900	.6170	.6229	.6163
75	.4946	.5073	.5743	.5524	.5902	.6167	.5997	.5893	.6163	.6224	.6157
76	.4937	.5063	.5736	.5517	.5895	.6160	.5990	.5886	.6156	.6218	.6152
77	.4928	.5053	.5730	.5510	.5888	.6154	.5984	.5879	.6149	.6213	.6146
78	.4919	.5044	.5724	.5503	.5881	.6147	.5977	.5872	.6142	.6207	.6140
79	.4910	.5034	.5717	.5496	.5874	.6140	.5970	.5865	.6135	.6202	.6135
80	.4901	.5024	.5711	.5489	.5867	.6134	.5964	.5858	.6128	.6196	.6129
81	.4893	.5014	.5704	.5482	.5860	.6127	.5957	.5851	.6121	.6191	.6124
82	.4884	.5004	.5698	.5475	.5853	.6120	.5951	.5844	.6114	.6185	.6118
83	.4875	.4994	.5691	.5468	.5846	.6114	.5944	.5837	.6106	.6179	.6112
84	.4866	.4984	.5685	.5461	.5839	.6107	.5937	.5830	.6099	.6174	.6106
85	.4856	.4974	.5678	.5454	.5832	.6100	.5931	.5823	.6092	.6168	.6101
86	.4847	.4964	.5672	.5447	.5824	.6093	.5924	.5816	.6085	.6163	.6095
87	.4838	.4954	.5665	.5440	.5817	.6086	.5917	.5809	.6078	.6157	.6089
88	.4829	.4944	.5659	.5433	.5810	.6080	.5911	.5802	.6071	.6152	.6084
89	.4820	.4933	.5652	.5426	.5803	.6073	.5904	.5795	.6064	.6146	.6078
90	.4811	.4923	.5645	.5419	.5796	.6066	.5897	.5788	.6056	.6140	.6072
91	.4801	.4912	.5639	.5411	.5789	.6059	.5891	.5780	.6049	.6135	.6066
92	.4792	.4902	.5632	.5404	.5781	.6052	.5884	.5773	.6042	.6129	.6061
93	.4783	.4891	.5626	.5397	.5774	.6046	.5877	.5766	.6035	.6124	.6055
94	.4773	.4881	.5619	.5390	.5767	.6039	.5870	.5759	.6028	.6118	.6049

*Propene also known as propylene; butene also known as butylene.

Table 1. Density in grams per milliliter (Cont'd)

Temp. °F	Propane	Propene*	Butane		Butene*				1,3-Butadiene	Pentane	
			n-	iso-	1-	cis-2	trans-2	iso-		n-	iso-
95	0.4764	0.4870	0.5612	0.5383	0.5760	0.6032	0.5863	0.5751	0.6020	0.6112	0.6043
96	.4754	.4860	.5606	.5375	.5752	.6025	.5857	.5744	.6013	.6107	.6037
97	.4745	.4849	.5599	.5368	.5745	.6018	.5850	.5737	.6006	.6101	.6032
98	.4735	.4838	.5592	.5361	.5738	.6011	.5843	.5730	.5999	.6095	.6026
99	.4725	.4827	.5586	.5353	.5730	.6004	.5836	.5722	.5991	.6090	.6020
100	.4716	.4816	.5579	.5346	.5723	.5997	.5829	.5715	.5984	.6084	.6014
101	.4706	.4805	.5572	.5339	.5715	.5990	.5822	.5708	.5976	.6078	.6008
102	.4696	.4794	.5565	.5332	.5708	.5983	.5815	.5700	.5969	.6073	.6003
103	.4686	.4783	.5558	.5324	.5701	.5976	.5808	.5693	.5962	.6067	.5997
104	.4676	.4772	.5552	.5317	.5693	.5969	.5802	.5685	.5954	.6061	.5991
105	.4666	.4761	.5545	.5309	.5686	.5962	.5795	.5678	.5947	.6056	.5985
106	.4656	.4750	.5538	.5302	.5678	.5955	.5788	.5670	.5940	.6050	.5979
107	.4646	.4738	.5531	.5294	.5671	.5948	.5781	.5663	.5932	.6044	.5973
108	.4636	.4727	.5524	.5287	.5663	.5941	.5774	.5655	.5925	.6039	.5967
109	.4625	.4715	.5518	.5280	.5656	.5934	.5767	.5648	.5917	.6033	.5962
110	.4615	.4704	.5511	.5272	.5648	.5927	.5760	.5640	.5910	.6027	.5956
111	.4605	.4692	.5504	.5264	.5640	.5920	.5752	.5633	.5902	.6021	.5950
112	.4595	.4681	.5497	.5257	.5633	.5913	.5745	.5625	.5895	.6016	.5944
113	.4584	.4669	.5490	.5249	.5625	.5906	.5738	.5618	.5887	.6010	.5938
114	.4574	.4657	.5483	.5242	.5617	.5899	.5731	.5610	.5879	.6004	.5932
115	.4563	.4645	.5476	.5234	.5610	.5892	.5724	.5602	.5872	.5998	.5926
116	.4552	.4633	.5469	.5226	.5602	.5884	.5717	.5595	.5864	.5992	.5920
117	.4542	.4621	.5462	.5219	.5594	.5877	.5710	.5587	.5856	.5987	.5914
118	.4531	.4609	.5455	.5211	.5586	.5870	.5703	.5579	.5849	.5981	.5908
119	.4520	.4596	.5448	.5203	.5579	.5863	.5695	.5571	.5841	.5975	.5902
120	.4509	.4584	.5441	.5196	.5571	.5856	.5688	.5564	.5833	.5969	.5896
122	.4486	.4559	.5427	.5180	.5555	.5841	.5674	.5548	.5818	.5957	.5884
124	.4464	.4534	.5413	.5164	.5539	.5826	.5659	.5532	.5802	.5946	.5872
126	.4441	.4508	.5398	.5149	.5523	.5812	.5645	.5516	.5787	.5934	.5859
128	.4418	.4483	.5384	.5133	.5507	.5797	.5630	.5500	.5771	.5922	.5847
130	.4394	.4457	.5369	.5117	.5491	.5782	.5616	.5484	.5755	.5910	.5835
132	.4370	.4430	.5355	.5100	.5475	.5767	.5601	.5468	.5739	.5899	.5823
134	.4346	.4403	.5340	.5084	.5458	.5752	.5586	.5451	.5723	.5887	.5810
136	.4321	.4376	.5325	.5068	.5442	.5737	.5571	.5435	.5707	.5875	.5798
138	.4296	.4349	.5310	.5051	.5425	.5722	.5556	.5418	.5691	.5863	.5785
140	.4270	.4321	.5295	.5034	.5409	.5707	.5541	.5402	.5675	.5851	.5773

*Propene also known as propylene; butene also known as butylene.

Table 2. Density in pounds per gallon

Temp. °F	Pro-pane	Pro-pene*	Butane		Butene*				1,3-Buta-diene	Pentane	
			n-	iso-	1-	cis-2	trans-2	iso-		n-	iso-
-50	4.877	5.061	5.405	5.254	5.590	5.790	5.637	5.579	5.812	5.745	5.695
-48	4.867	5.049	5.396	5.245	5.580	5.781	5.627	5.569	5.801	5.737	5.686
-46	4.856	5.038	5.386	5.235	5.570	5.771	5.617	5.559	5.791	5.728	5.678
-44	4.846	5.026	5.377	5.226	5.560	5.761	5.608	5.549	5.781	5.719	5.669
-42	4.836	5.015	5.368	5.216	5.550	5.751	5.598	5.539	5.771	5.711	5.661
-40	4.825	5.003	5.359	5.207	5.540	5.742	5.588	5.529	5.761	5.702	5.652
-38	4.814	4.991	5.349	5.197	5.530	5.732	5.579	5.519	5.751	5.693	5.643
-36	4.804	4.980	5.340	5.187	5.520	5.722	5.569	5.509	5.740	5.685	5.635
-34	4.793	4.968	5.331	5.178	5.510	5.712	5.559	5.499	5.730	5.676	5.626
-32	4.782	4.956	5.321	5.168	5.500	5.702	5.550	5.489	5.720	5.667	5.617
-30	4.772	4.945	5.312	5.158	5.490	5.692	5.540	5.479	5.710	5.659	5.609
-28	4.761	4.933	5.303	5.149	5.479	5.682	5.530	5.469	5.700	5.650	5.600
-26	4.750	4.921	5.293	5.139	5.469	5.672	5.521	5.459	5.689	5.642	5.591
-24	4.739	4.909	5.284	5.129	5.459	5.662	5.511	5.449	5.679	5.633	5.583
-22	4.728	4.897	5.275	5.119	5.449	5.652	5.501	5.439	5.669	5.624	5.574
-20	4.717	4.885	5.265	5.110	5.439	5.642	5.491	5.429	5.659	5.616	5.565
-18	4.706	4.873	5.256	5.100	5.428	5.632	5.482	5.418	5.648	5.607	5.556
-16	4.695	4.861	5.246	5.090	5.418	5.622	5.472	5.408	5.638	5.598	5.548
-14	4.684	4.849	5.237	5.080	5.408	5.612	5.462	5.398	5.628	5.590	5.539
-12	4.673	4.836	5.227	5.070	5.398	5.602	5.452	5.388	5.617	5.581	5.530
-10	4.662	4.824	5.218	5.060	5.387	5.592	5.442	5.378	5.607	5.572	5.521
-8	4.651	4.812	5.208	5.050	5.377	5.582	5.432	5.367	5.596	5.564	5.513
-6	4.640	4.799	5.199	5.040	5.367	5.572	5.423	5.357	5.586	5.555	5.504
-4	4.628	4.787	5.189	5.030	5.356	5.562	5.413	5.347	5.576	5.546	5.495
-2	4.617	4.774	5.180	5.020	5.346	5.552	5.403	5.337	5.565	5.537	5.486
0	4.605	4.762	5.170	5.010	5.336	5.542	5.393	5.326	5.555	5.529	5.478
1	4.600	4.756	5.166	5.005	5.330	5.537	5.388	5.321	5.550	5.524	5.473
2	4.594	4.749	5.161	5.000	5.325	5.532	5.383	5.316	5.544	5.520	5.469
3	4.588	4.743	5.156	4.995	5.320	5.527	5.378	5.311	5.539	5.516	5.465
4	4.583	4.736	5.151	4.990	5.315	5.522	5.373	5.305	5.534	5.511	5.460
5	4.577	4.730	5.146	4.985	5.310	5.516	5.368	5.300	5.529	5.507	5.456
6	4.571	4.724	5.141	4.980	5.304	5.511	5.363	5.295	5.523	5.503	5.451
7	4.565	4.717	5.137	4.975	5.299	5.506	5.358	5.290	5.518	5.498	5.447
8	4.559	4.711	5.132	4.970	5.294	5.501	5.353	5.284	5.513	5.494	5.443
9	4.553	4.704	5.127	4.965	5.289	5.496	5.348	5.279	5.508	5.489	5.438
10	4.548	4.698	5.122	4.960	5.283	5.491	5.343	5.274	5.502	5.485	5.434
11	4.542	4.691	5.117	4.955	5.278	5.486	5.338	5.269	5.497	5.480	5.429
12	4.536	4.685	5.112	4.950	5.273	5.481	5.333	5.264	5.492	5.476	5.425
13	4.530	4.678	5.108	4.945	5.268	5.476	5.328	5.258	5.486	5.472	5.420
14	4.524	4.672	5.103	4.940	5.262	5.471	5.323	5.253	5.481	5.467	5.416

*Propene also known as propylene; butene also known as butylene.

Table 2. Density in pounds per gallon (Cont'd)

Temp. °F	Propane	Propene*	Butane n-	Butane iso-	Butene* 1-	Butene* cis-2	Butene* trans-2	Butene* iso-	1,3-Butadiene	Pentane n-	Pentane iso-
15	4.518	4.665	5.098	4.934	5.257	5.465	5.318	5.248	5.476	5.463	5.412
16	4.512	4.659	5.093	4.929	5.252	5.460	5.313	5.243	5.470	5.459	5.407
17	4.506	4.652	5.088	4.924	5.246	5.455	5.308	5.237	5.465	5.454	5.403
18	4.500	4.645	5.083	4.919	5.241	5.450	5.303	5.232	5.460	5.450	5.398
19	4.494	4.639	5.078	4.914	5.236	5.445	5.298	5.227	5.454	5.445	5.394
20	4.488	4.632	5.074	4.909	5.231	5.440	5.293	5.222	5.449	5.441	5.389
21	4.482	4.625	5.069	4.904	5.225	5.435	5.288	5.216	5.444	5.437	5.385
22	4.476	4.619	5.064	4.898	5.220	5.430	5.283	5.211	5.438	5.432	5.380
23	4.470	4.612	5.059	4.893	5.214	5.424	5.278	5.206	5.433	5.428	5.376
24	4.464	4.605	5.054	4.888	5.209	5.419	5.273	5.200	5.428	5.423	5.371
25	4.458	4.599	5.049	4.883	5.204	5.414	5.267	5.195	5.422	5.419	5.367
26	4.452	4.592	5.044	4.878	5.198	5.409	5.262	5.190	5.417	5.415	5.362
27	4.446	4.585	5.039	4.873	5.193	5.404	5.257	5.184	5.411	5.410	5.358
28	4.439	4.578	5.034	4.867	5.188	5.398	5.252	5.179	5.406	5.406	5.353
29	4.433	4.572	5.029	4.862	5.182	5.393	5.247	5.174	5.400	5.401	5.349
30	4.427	4.565	5.024	4.857	5.177	5.388	5.242	5.168	5.395	5.397	5.345
31	4.421	4.558	5.019	4.851	5.172	5.383	5.237	5.163	5.390	5.393	5.340
32	4.415	4.551	5.014	4.846	5.166	5.377	5.232	5.158	5.384	5.388	5.336
33	4.409	4.544	5.009	4.841	5.161	5.372	5.226	5.152	5.379	5.384	5.331
34	4.402	4.537	5.004	4.836	5.155	5.367	5.221	5.147	5.373	5.379	5.327
35	4.396	4.530	4.999	4.830	5.150	5.362	5.216	5.141	5.368	5.375	5.322
36	4.390	4.523	4.994	4.825	5.144	5.357	5.211	5.136	5.363	5.370	5.318
37	4.383	4.517	4.989	4.820	5.139	5.351	5.206	5.131	5.357	5.366	5.313
38	4.377	4.510	4.984	4.814	5.133	5.346	5.201	5.125	5.352	5.361	5.309
39	4.371	4.503	4.979	4.809	5.128	5.341	5.196	5.120	5.346	5.357	5.304
40	4.364	4.496	4.974	4.804	5.123	5.336	5.190	5.114	5.341	5.352	5.300
41	4.358	4.489	4.969	4.798	5.117	5.330	5.185	5.109	5.335	5.348	5.295
42	4.352	4.482	4.964	4.793	5.112	5.325	5.180	5.103	5.330	5.344	5.291
43	4.345	4.474	4.959	4.788	5.106	5.320	5.175	5.098	5.324	5.339	5.286
44	4.339	4.467	4.954	4.782	5.101	5.314	5.170	5.092	5.319	5.335	5.281
45	4.332	4.460	4.949	4.777	5.095	5.309	5.165	5.087	5.313	5.330	5.277
46	4.326	4.453	4.944	4.771	5.090	5.304	5.159	5.081	5.308	5.326	5.272
47	4.319	4.446	4.939	4.766	5.084	5.298	5.154	5.076	5.302	5.321	5.268
48	4.313	4.439	4.934	4.761	5.078	5.293	5.149	5.070	5.296	5.317	5.263
49	4.306	4.431	4.929	4.755	5.073	5.288	5.143	5.065	5.291	5.312	5.259
50	4.300	4.424	4.923	4.750	5.067	5.282	5.138	5.059	5.285	5.308	5.254
51	4.293	4.417	4.918	4.744	5.062	5.277	5.133	5.054	5.280	5.303	5.250
52	4.286	4.410	4.913	4.739	5.056	5.272	5.128	5.048	5.274	5.299	5.245
53	4.280	4.402	4.908	4.733	5.051	5.266	5.122	5.043	5.269	5.294	5.240
54	4.273	4.395	4.903	4.728	5.045	5.261	5.117	5.037	5.263	5.290	5.236

*Propene also known as propylene; butene also known as butylene.

Table 2. Density in pounds per gallon (Cont'd)

Temp.			Butane		Butene*				1,3-	Pentane	
°F	Propane	Propene*	n-	iso-	1-	cis-2	trans-2	iso-	Butadiene	n-	iso-
55	4.266	4.387	4.898	4.722	5.039	5.256	5.112	5.032	5.257	5.285	5.231
56	4.260	4.380	4.892	4.717	5.034	5.250	5.107	5.026	5.252	5.281	5.227
57	4.253	4.373	4.887	4.711	5.028	5.245	5.101	5.021	5.246	5.276	5.222
58	4.246	4.365	4.882	4.706	5.022	5.239	5.096	5.015	5.240	5.272	5.217
59	4.239	4.358	4.877	4.700	5.017	5.234	5.091	5.009	5.235	5.267	5.213
60	4.233	4.350	4.872	4.695	5.011	5.229	5.085	5.004	5.229	5.262	5.208
61	4.226	4.343	4.867	4.689	5.006	5.223	5.080	4.998	5.224	5.258	5.203
62	4.219	4.335	4.861	4.683	5.000	5.218	5.075	4.993	5.218	5.253	5.199
63	4.212	4.327	4.856	4.678	4.994	5.212	5.070	4.987	5.212	5.249	5.194
64	4.205	4.320	4.851	4.672	4.989	5.207	5.064	4.981	5.206	5.244	5.190
65	4.198	4.312	4.846	4.667	4.983	5.202	5.059	4.975	5.201	5.240	5.185
66	4.191	4.304	4.840	4.661	4.977	5.196	5.053	4.970	5.195	5.235	5.130
67	4.184	4.296	4.835	4.655	4.971	5.191	5.048	4.964	5.189	5.231	5.176
68	4.177	4.289	4.830	4.650	4.966	5.185	5.042	4.958	5.184	5.226	5.171
69	4.170	4.281	4.825	4.644	4.960	5.180	5.037	4.953	5.178	5.222	5.167
70	4.163	4.273	4.819	4.638	4.954	5.174	5.032	4.947	5.172	5.217	5.162
71	4.156	4.265	4.814	4.633	4.949	5.169	5.026	4.941	5.166	5.212	5.157
72	4.149	4.257	4.809	4.627	4.943	5.163	5.021	4.935	5.160	5.208	5.153
73	4.141	4.249	4.803	4.621	4.937	5.158	5.015	4.930	5.155	5.203	5.148
74	4.134	4.241	4.798	4.615	4.931	5.152	5.010	4.924	5.149	5.199	5.143
75	4.127	4.233	4.792	4.610	4.925	5.146	5.004	4.918	5.143	5.194	5.138
76	4.120	4.225	4.787	4.604	4.920	5.141	4.999	4.912	5.137	5.189	5.134
77	4.113	4.217	4.782	4.598	4.914	5.135	4.993	4.907	5.131	5.185	5.129
78	4.105	4.209	4.776	4.592	4.908	5.130	4.988	4.901	5.125	5.180	5.124
79	4.098	4.201	4.771	4.587	4.902	5.124	4.982	4.895	5.120	5.176	5.120
80	4.090	4.192	4.766	4.581	4.896	5.119	4.977	4.889	5.114	5.171	5.115
81	4.083	4.184	4.760	4.575	4.890	5.113	4.971	4.883	5.108	5.166	5.110
82	4.075	4.176	4.755	4.569	4.884	5.107	4.966	4.877	5.102	5.162	5.105
83	4.068	4.168	4.749	4.563	4.878	5.102	4.960	4.871	5.096	5.157	5.101
84	4.060	4.159	4.744	4.557	4.873	5.096	4.955	4.866	5.090	5.152	5.096
85	4.053	4.151	4.739	4.551	4.867	5.091	4.949	4.860	5.084	5.148	5.091
86	4.045	4.142	4.733	4.546	4.861	5.085	4.944	4.854	5.078	5.143	5.086
87	4.038	4.134	4.728	4.540	4.855	5.079	4.938	4.848	5.072	5.138	5.082
88	4.030	4.125	4.722	4.534	4.849	5.074	4.933	4.842	5.066	5.134	5.077
89	4.022	4.117	4.717	4.528	4.843	5.068	4.927	4.836	5.060	5.129	5.072
90	4.015	4.108	4.711	4.522	4.837	5.062	4.921	4.830	5.054	5.124	5.067
91	4.007	4.099	4.706	4.516	4.831	5.057	4.916	4.824	5.048	5.120	5.062
92	3.999	4.091	4.700	4.510	4.825	5.051	4.910	4.818	5.042	5.115	5.058
93	3.991	4.082	4.695	4.504	4.819	5.045	4.904	4.812	5.036	5.110	5.053
94	3.983	4.073	4.689	4.498	4.813	5.039	4.899	4.806	5.030	5.106	5.048

*Propene also known as propylene; butene also known as butylene.

Table 2. Density in pounds per gallon (Cont'd)

Temp.			Butane		B u t e n e *				1,3-	Pentane	
°F	Propane	Propene*	n-	iso-	1-	cis-2	trans -2	iso-	Butadiene	n-	iso-
95	3.975	4.064	4.684	4.492	4.807	5.034	4.893	4.800	5.024	5.101	5.043
96	3.967	4.055	4.678	4.486	4.800	5.028	4.888	4.794	5.018	5.096	5.038
97	3.959	4.046	4.672	4.480	4.794	5.022	4.882	4.788	5.012	5.091	5.034
98	3.951	4.037	4.667	4.474	4.788	5.016	4.876	4.782	5.006	5.087	5.029
99	3.943	4.028	4.661	4.468	4.782	5.011	4.870	4.775	5.000	5.082	5.024
100	3.935	4.019	4.656	4.462	4.776	5.005	4.865	4.769	4.994	5.077	5.019
101	3.927	4.010	4.650	4.455	4.770	4.999	4.859	4.763	4.987	5.073	5.014
102	3.919	4.001	4.644	4.449	4.764	4.993	4.853	4.757	4.981	5.068	5.009
103	3.911	3.992	4.639	4.443	4.757	4.987	4.847	4.751	4.975	5.063	5.004
104	3.902	3.982	4.633	4.437	4.751	4.982	4.842	4.745	4.969	5.058	5.000
105	3.894	3.973	4.627	4.431	4.745	4.976	4.836	4.738	4.963	5.054	4.995
106	3.885	3.964	4.622	4.424	4.739	4.970	4.830	4.732	4.957	5.049	4.990
107	3.877	3.954	4.616	4.418	4.732	4.964	4.824	4.726	4.950	5.044	4.985
108	3.869	3.945	4.610	4.412	4.726	4.958	4.818	4.720	4.944	5.039	4.980
109	3.860	3.935	4.605	4.406	4.720	4.952	4.812	4.713	4.938	5.035	4.975
110	3.852	3.925	4.599	4.400	4.713	4.946	4.806	4.707	4.932	5.030	4.970
111	3.843	3.916	4.593	4.393	4.707	4.940	4.800	4.701	4.925	5.025	4.965
112	3.834	3.906	4.587	4.387	4.701	4.934	4.795	4.694	4.919	5.020	4.960
113	3.826	3.896	4.582	4.381	4.694	4.929	4.789	4.688	4.913	5.015	4.955
114	3.817	3.886	4.576	4.374	4.688	4.923	4.783	4.682	4.906	5.010	4.950
115	3.808	3.876	4.570	4.368	4.681	4.917	4.777	4.675	4.900	5.006	4.945
116	3.799	3.866	4.564	4.361	4.675	4.911	4.771	4.669	4.894	5.001	4.940
117	3.790	3.856	4.558	4.355	4.668	4.905	4.765	4.662	4.887	4.996	4.935
118	3.781	3.846	4.552	4.349	4.662	4.899	4.759	4.656	4.881	4.991	4.930
119	3.772	3.836	4.547	4.342	4.656	4.893	4.753	4.649	4.874	4.986	4.925
120	3.763	3.825	4.541	4.336	4.649	4.887	4.747	4.643	4.868	4.981	4.920
122	3.744	3.805	4.529	4.323	4.636	4.874	4.735	4.630	4.855	4.972	4.910
124	3.725	3.784	4.517	4.310	4.623	4.862	4.723	4.617	4.842	4.962	4.900
126	3.706	3.762	4.505	4.297	4.609	4.850	4.711	4.603	4.829	4.952	4.890
128	3.687	3.741	4.493	4.283	4.596	4.838	4.698	4.590	4.816	4.942	4.880
130	3.667	3.719	4.481	4.270	4.582	4.825	4.686	4.577	4.803	4.932	4.869
132	3.647	3.697	4.469	4.256	4.569	4.813	4.674	4.563	4.789	4.922	4.859
134	3.626	3.675	4.456	4.243	4.555	4.800	4.661	4.549	4.776	4.912	4.849
136	3.606	3.652	4.444	4.229	4.541	4.788	4.649	4.536	4.763	4.902	4.838
138	3.585	3.629	4.431	4.215	4.528	4.775	4.637	4.522	4.749	4.892	4.828
140	3.563	3.606	4.419	4.201	4.514	4.763	4.624	4.508	4.736	4.882	4.818

*Propene also known as propylene; butene also known as butylene.

Table 3. Volume at 60°F occupied by unit volume at temperature indicated

Temp. °F	Propane	Propene*	Butane n-	Butane iso-	Butene* 1-	Butene* cis-2	Butene* trans-2	Butene* iso-	1,3-Butadiene	Pentane n-	Pentane iso-
-50	1.1524	1.1633	1.1094	1.1192	1.1155	1.1074	1.1084	1.1149	1.1114	1.0917	1.0935
-48	1.1499	1.1607	1.1075	1.1172	1.1135	1.1056	1.1065	1.1129	1.1094	1.0901	1.0918
-46	1.1474	1.1580	1.1056	1.1152	1.1115	1.1037	1.1046	1.1109	1.1075	1.0884	1.0902
-44	1.1450	1.1554	1.1037	1.1131	1.1095	1.1018	1.1027	1.1090	1.1056	1.0868	1.0885
-42	1.1425	1.1527	1.1018	1.1111	1.1075	1.0999	1.1008	1.1070	1.1036	1.0852	1.0868
-40	1.1400	1.1501	1.0999	1.1091	1.1055	1.0981	1.0989	1.1050	1.1017	1.0835	1.0852
-38	1.1375	1.1474	1.0980	1.1070	1.1035	1.0962	1.0970	1.1030	1.0997	1.0819	1.0835
-36	1.1350	1.1447	1.0961	1.1050	1.1015	1.0943	1.0951	1.1010	1.0978	1.0802	1.0819
-34	1.1325	1.1420	1.0942	1.1029	1.0995	1.0924	1.0932	1.0990	1.0958	1.0786	1.0802
-32	1.1300	1.1394	1.0923	1.1008	1.0975	1.0905	1.0913	1.0970	1.0939	1.0770	1.0785
-30	1.1274	1.1367	1.0904	1.0988	1.0954	1.0886	1.0894	1.0950	1.0919	1.0753	1.0769
-28	1.1248	1.1339	1.0885	1.0967	1.0934	1.0867	1.0875	1.0930	1.0900	1.0737	1.0752
-26	1.1223	1.1312	1.0865	1.0946	1.0914	1.0848	1.0856	1.0910	1.0880	1.0720	1.0735
-24	1.1197	1.1285	1.0846	1.0926	1.0894	1.0829	1.0837	1.0889	1.0861	1.0704	1.0719
-22	1.1171	1.1257	1.0827	1.0905	1.0873	1.0810	1.0818	1.0869	1.0841	1.0687	1.0702
-20	1.1146	1.1230	1.0807	1.0884	1.0853	1.0791	1.0798	1.0849	1.0821	1.0671	1.0685
-18	1.1120	1.1202	1.0788	1.0863	1.0832	1.0772	1.0779	1.0829	1.0801	1.0654	1.0668
-16	1.1094	1.1174	1.0769	1.0842	1.0812	1.0753	1.0760	1.0808	1.0782	1.0638	1.0652
-14	1.1068	1.1146	1.0749	1.0821	1.0791	1.0734	1.0741	1.0788	1.0762	1.0621	1.0635
-12	1.1041	1.1118	1.0730	1.0800	1.0771	1.0715	1.0721	1.0768	1.0742	1.0605	1.0618
-10	1.1015	1.1090	1.0711	1.0779	1.0751	1.0696	1.0702	1.0747	1.0722	1.0588	1.0601
-8	1.0988	1.1061	1.0691	1.0758	1.0730	1.0676	1.0683	1.0727	1.0702	1.0572	1.0585
-6	1.0962	1.1033	1.0671	1.0737	1.0709	1.0657	1.0663	1.0706	1.0683	1.0555	1.0568
-4	1.0935	1.1004	1.0652	1.0715	1.0689	1.0638	1.0644	1.0686	1.0663	1.0539	1.0551
-2	1.0908	1.0976	1.0632	1.0694	1.0668	1.0618	1.0624	1.0665	1.0643	1.0523	1.0534
0	1.0881	1.0947	1.0613	1.0673	1.0647	1.0599	1.0605	1.0644	1.0623	1.0506	1.0517
1	1.0868	1.0932	1.0603	1.0662	1.0637	1.0589	1.0595	1.0634	1.0613	1.0497	1.0509
2	1.0854	1.0917	1.0593	1.0651	1.0627	1.0580	1.0585	1.0624	1.0603	1.0489	1.0500
3	1.0841	1.0903	1.0583	1.0641	1.0616	1.0570	1.0575	1.0613	1.0593	1.0481	1.0492
4	1.0827	1.0888	1.0574	1.0630	1.0606	1.0560	1.0566	1.0603	1.0582	1.0473	1.0484
5	1.0813	1.0873	1.0564	1.0619	1.0595	1.0550	1.0556	1.0593	1.0572	1.0464	1.0475
6	1.0800	1.0859	1.0554	1.0608	1.0585	1.0541	1.0546	1.0582	1.0562	1.0456	1.0467
7	1.0786	1.0844	1.0544	1.0598	1.0575	1.0531	1.0537	1.0572	1.0552	1.0448	1.0458
8	1.0772	1.0829	1.0534	1.0587	1.0564	1.0521	1.0527	1.0561	1.0542	1.0439	1.0450
9	1.0758	1.0814	1.0524	1.0576	1.0554	1.0512	1.0517	1.0551	1.0532	1.0431	1.0441
10	1.0744	1.0800	1.0514	1.0565	1.0543	1.0502	1.0507	1.0541	1.0522	1.0423	1.0433
11	1.0731	1.0785	1.0504	1.0554	1.0533	1.0492	1.0497	1.0530	1.0512	1.0414	1.0424
12	1.0717	1.0770	1.0494	1.0544	1.0522	1.0482	1.0487	1.0520	1.0502	1.0406	1.0416
13	1.0703	1.0755	1.0484	1.0533	1.0512	1.0472	1.0477	1.0509	1.0492	1.0398	1.0407
14	1.0689	1.0740	1.0474	1.0522	1.0501	1.0463	1.0468	1.0499	1.0481	1.0390	1.0399

*Propene also known as propylene; butene also known as butylene.

Table 3. Volume at 60°F occupied by unit volume at temperature indicated (Cont'd)

Temp.			Butane		Butene*				1,3-	Pentane	
°F	Propane	Propene*	n-	iso-	1-	cis-2	trans-2	iso-	Butadiene	n-	iso-
15	1.0675	1.0724	1.0464	1.0511	1.0490	1.0453	1.0458	1.0488	1.0471	1.0381	1.0391
16	1.0661	1.0709	1.0454	1.0500	1.0480	1.0443	1.0448	1.0478	1.0461	1.0373	1.0382
17	1.0647	1.0694	1.0444	1.0489	1.0469	1.0433	1.0438	1.0467	1.0451	1.0364	1.0373
18	1.0632	1.0679	1.0434	1.0478	1.0459	1.0423	1.0428	1.0457	1.0441	1.0356	1.0365
19	1.0618	1.0664	1.0424	1.0467	1.0448	1.0414	1.0418	1.0446	1.0431	1.0348	1.0356
20	1.0604	1.0648	1.0414	1.0456	1.0437	1.0404	1.0408	1.0435	1.0420	1.0339	1.0348
21	1.0590	1.0633	1.0404	1.0445	1.0427	1.0394	1.0398	1.0425	1.0410	1.0331	1.0339
22	1.0576	1.0618	1.0394	1.0434	1.0416	1.0384	1.0388	1.0414	1.0400	1.0323	1.0330
23	1.0561	1.0602	1.0384	1.0423	1.0405	1.0374	1.0378	1.0404	1.0390	1.0314	1.0322
24	1.0547	1.0587	1.0374	1.0412	1.0395	1.0364	1.0368	1.0393	1.0379	1.0306	1.0313
25	1.0532	1.0571	1.0363	1.0401	1.0384	1.0354	1.0358	1.0382	1.0369	1.0298	1.0305
26	1.0518	1.0556	1.0353	1.0390	1.0373	1.0345	1.0348	1.0372	1.0359	1.0289	1.0296
27	1.0504	1.0540	1.0343	1.0379	1.0362	1.0335	1.0338	1.0361	1.0348	1.0281	1.0287
28	1.0489	1.0525	1.0333	1.0368	1.0352	1.0325	1.0328	1.0350	1.0338	1.0272	1.0279
29	1.0474	1.0509	1.0323	1.0357	1.0341	1.0315	1.0318	1.0340	1.0328	1.0264	1.0270
30	1.0460	1.0493	1.0313	1.0345	1.0331	1.0305	1.0308	1.0329	1.0317	1.0255	1.0262
31	1.0445	1.0478	1.0303	1.0334	1.0320	1.0295	1.0298	1.0318	1.0307	1.0247	1.0253
32	1.0431	1.0462	1.0292	1.0323	1.0309	1.0285	1.0288	1.0308	1.0297	1.0239	1.0245
33	1.0416	1.0446	1.0282	1.0312	1.0298	1.0275	1.0277	1.0297	1.0286	1.0230	1.0236
34	1.0401	1.0430	1.0272	1.0300	1.0287	1.0265	1.0267	1.0286	1.0276	1.0222	1.0227
35	1.0386	1.0414	1.0262	1.0289	1.0276	1.0255	1.0257	1.0275	1.0265	1.0213	1.0218
36	1.0372	1.0398	1.0251	1.0278	1.0266	1.0245	1.0247	1.0264	1.0255	1.0205	1.0210
37	1.0357	1.0383	1.0241	1.0266	1.0255	1.0234	1.0237	1.0254	1.0244	1.0196	1.0202
38	1.0342	1.0367	1.0231	1.0255	1.0244	1.0224	1.0227	1.0243	1.0234	1.0188	1.0193
39	1.0327	1.0351	1.0220	1.0244	1.0233	1.0214	1.0217	1.0232	1.0224	1.0179	1.0184
40	1.0312	1.0334	1.0210	1.0232	1.0222	1.0204	1.0207	1.0221	1.0213	1.0171	1.0175
41	1.0296	1.0318	1.0200	1.0221	1.0211	1.0194	1.0196	1.0210	1.0203	1.0162	1.0167
42	1.0281	1.0302	1.0190	1.0209	1.0200	1.0184	1.0186	1.0199	1.0192	1.0154	1.0158
43	1.0266	1.0286	1.0179	1.0198	1.0189	1.0174	1.0176	1.0188	1.0182	1.0145	1.0149
44	1.0251	1.2070	1.0169	1.0186	1.0178	1.0164	1.0166	1.0177	1.0171	1.0137	1.0141
45	1.0235	1.0253	1.0158	1.0175	1.0167	1.0154	1.0156	1.0166	1.0161	1.0128	1.0132
46	1.0220	1.0237	1.0148	1.0163	1.0156	1.0144	1.0145	1.0155	1.0150	1.0120	1.0123
47	1.0205	1.0220	1.0137	1.0152	1.0145	1.0133	1.0135	1.0144	1.0139	1.0111	1.0114
48	1.0189	1.0204	1.0127	1.0140	1.0134	1.0123	1.0125	1.0133	1.0129	1.0103	1.0106
49	1.0174	1.0187	1.0117	1.0129	1.0123	1.0113	1.0114	1.0122	1.0118	1.0094	1.0097
50	1.0159	1.0170	1.0106	1.0117	1.0112	1.0103	1.0104	1.0111	1.0107	1.0086	1.0088
51	1.0143	1.0154	1.0096	1.0106	1.0101	1.0093	1.0094	1.0101	1.0097	1.0077	1.0080
52	1.0127	1.0137	1.0085	1.0094	1.0090	1.0082	1.0083	1.0089	1.0086	1.0069	1.0071
53	1.0112	1.0120	1.0074	1.0083	1.0078	1.0072	1.0073	1.0078	1.0075	1.0060	1.0062
54	1.0096	1.0103	1.0064	1.0071	1.0067	1.0062	1.0063	1.0067	1.0065	1.0052	1.0053

*Propene also known as propylene; butene also known as butylene.

Table 3. Volume at 60°F occupied by unit volume at temperature indicated (Cont'd)

Temp. °F	Propane	Propene*	Butane		Butene*				1,3-Butadiene	Pentane	
			n-	iso-	1-	cis-2	trans-2	iso-		n-	iso-
55	1.0080	1.0086	1.0053	1.0059	1.0056	1.0052	1.0052	1.0056	1.0054	1.0043	1.0045
56	1.0064	1.0069	1.0042	1.0047	1.0045	1.0041	1.0042	1.0045	1.0043	1.0034	1.0036
57	1.0048	1.0052	1.0032	1.0035	1.0034	1.0031	1.0031	1.0034	1.0032	1.0026	1.0027
58	1.0032	1.0035	1.0021	1.0024	1.0022	1.0021	1.0021	1.0022	1.0022	1.0017	1.0018
59	1.0016	1.0017	1.0011	1.0012	1.0011	1.0010	1.0011	1.0011	1.0011	1.0009	1.0009
60	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
61	0.9984	0.9983	0.9989	0.9988	0.9989	0.9990	0.9989	0.9989	0.9989	0.9991	0.9991
62	.9968	.9965	.9978	.9976	.9977	.9979	.9979	.9978	.9978	.9983	.9982
63	.9951	.9947	.9968	.9964	.9966	.9969	.9969	.9966	.9967	.9974	.9973
64	.9935	.9930	.9957	.9952	.9955	.9958	.9958	.9955	.9956	.9965	.9964
65	.9919	.9912	.9946	.9940	.9943	.9948	.9947	.9944	.9946	.9957	.9955
66	.9902	.9895	.9935	.9928	.9932	.9937	.9937	.9932	.9935	.9948	.9947
67	.9886	.9877	.9925	.9916	.9921	.9927	.9926	.9921	.9924	.9940	.9938
68	.9869	.9859	.9914	.9904	.9909	.9917	.9916	.9910	.9913	.9931	.9929
69	.9852	.9841	.9903	.9892	.9898	.9906	.9905	.9898	.9902	.9922	.9920
70	.9836	.9823	.9892	.9880	.9886	.9896	.9894	.9887	.9891	.9913	.9911
71	.9819	.9805	.9881	.9868	.9875	.9885	.9884	.9875	.9880	.9905	.9902
72	.9802	.9786	.9870	.9856	.9863	.9875	.9873	.9864	.9868	.9896	.9893
73	.9785	.9768	.9859	.9844	.9852	.9864	.9862	.9852	.9857	.9887	.9884
74	.9768	.9750	.9848	.9831	.9840	.9853	.9852	.9841	.9846	.9878	.9875
75	.9751	.9731	.9837	.9819	.9828	.9843	.9841	.9829	.9835	.9870	.9866
76	.9734	.9713	.9826	.9807	.9817	.9832	.9830	.9817	.9824	.9861	.9857
77	.9717	.9694	.9815	.9795	.9805	.9822	.9819	.9806	.9813	.9852	.9848
78	.9699	.9675	.9804	.9782	.9794	.9811	.9809	.9794	.9802	.9843	.9839
79	.9682	.9657	.9793	.9770	.9782	.9800	.9798	.9783	.9790	.9835	.9830
80	.9664	.9638	.9782	.9758	.9770	.9789	.9787	.9771	.9779	.9826	.9821
81	.9647	.9619	.9771	.9745	.9758	.9779	.9776	.9759	.9768	.9817	.9812
82	.9629	.9600	.9760	.9732	.9747	.9768	.9765	.9748	.9757	.9808	.9803
83	.9611	.9580	.9749	.9720	.9735	.9757	.9754	.9736	.9645	.9799	.9793
84	.9594	.9561	.9738	.9708	.9723	.9747	.9743	.9724	.9734	.9791	.9784
85	.9576	.9542	.9727	.9695	.9711	.9736	.9733	.9712	.9723	.9782	.9775
86	.9558	.9523	.9715	.9683	.9699	.9725	.9722	.9700	.9711	.9773	.9766
87	.9540	.9503	.9704	.9670	.9687	.9714	.9711	.9688	.9700	.9764	.9757
88	.9522	.9484	.9693	.9657	.9675	.9703	.9700	.9676	.9688	.9755	.9748
89	.9503	.9464	.9682	.9645	.9664	.9692	.9689	.9665	.9677	.9746	.9739
90	.9485	.9444	.9670	.9632	.9652	.9682	.9678	.9653	.9665	.9737	.9729
91	.9467	.9424	.9659	.9619	.9640	.9671	.9667	.9641	.9654	.9729	.9720
92	.9448	.9404	.9648	.9607	.9627	.9660	.9656	.9629	.9642	.9720	.9711
93	.9430	.9384	.9637	.9594	.9615	.9649	.9644	.9617	.9631	.9711	.9702
94	.9411	.9363	.9625	.9581	.9603	.9638	.9633	.9605	.9619	.9702	.9693

*Propene also known as propylene; butene also known as butylene.

Table 3. Volume at 60°F occupied by unit volume at temperature indicated (Cont'd)

Temp.			Butane		Butene*				1,3-	Pentane	
°F	Propane	Propene*	n-	iso-	1-	cis-2	trans-2	iso-	Butadiene	n-	iso-
95	0.9393	0.9343	0.9614	0.9568	0.9591	0.9627	0.9622	0.9592	0.9608	0.9693	0.9683
96	.9374	.9322	.9602	.9555	.9579	.9616	.9611	.9580	.9596	.9684	.9674
97	.9355	.9302	.9591	.9542	.9567	.9605	.9600	.9568	.9585	.9675	.9665
98	.9336	.9281	.9579	.9529	.9555	.9594	.9589	.9556	.9573	.9666	.9655
99	.9317	.9261	.9568	.9516	.9543	.9583	.9577	.9544	.9561	.9657	.9646
100	.9298	.9240	.9556	.9503	.9530	.9572	.9566	.9532	.9549	.9648	.9637
101	.9278	.9219	.9545	.9490	.9518	.9561	.9555	.9519	.9538	.9639	.9627
102	.9259	.9198	.9533	.9477	.9506	.9550	.9543	.9507	.9526	.9630	.9618
103	.9239	.9176	.9521	.9464	.9493	.9538	.9532	.9494	.9514	.9621	.9609
104	.9220	.9155	.9510	.9451	.9481	.9527	.9521	.9482	.9503	.9612	.9599
105	.9200	.9134	.9498	.9438	.9468	.9516	.9509	.9470	.9491	.9603	.9590
106	.9180	.9112	.9486	.9425	.9456	.9505	.9498	.9457	.9479	.9594	.9581
107	.9160	.9090	.9475	.9411	.9443	.9494	.9486	.9445	.9467	.9585	.9571
108	.9140	.9068	.9463	.9398	.9431	.9482	.9475	.9432	.9455	.9576	.9562
109	.9120	.9046	.9452	.9385	.9418	.9471	.9463	.9420	.9443	.9567	.9552
110	.9100	.9024	.9440	.9372	.9405	.9460	.9452	.9407	.9431	.9558	.9543
111	.9080	.9002	.9428	.9358	.9393	.9449	.9440	.9394	.9419	.9548	.9533
112	.9059	.8979	.9416	.9345	.9380	.9437	.9428	.9382	.9407	.9539	.9524
113	.9038	.8956	.9404	.9331	.9367	.9426	.9417	.9369	.9395	.9530	.9514
114	.9018	.8934	.9392	.9318	.9355	.9415	.9405	.9356	.9383	.9521	.9505
115	.8997	.8911	.9380	.9304	.9342	.9403	.9393	.9343	.9371	.9512	.9495
116	.8976	.8888	.9368	.9291	.9329	.9392	.9381	.9331	.9358	.9503	.9485
117	.8954	.8864	.9356	.9277	.9316	.9380	.9370	.9318	.9346	.9493	.9476
118	.8933	.8841	.9344	.9263	.9303	.9369	.9358	.9305	.9334	.9484	.9466
119	.8911	.8818	.9332	.9249	.9290	.9357	.9346	.9292	.9322	.9475	.9457
120	.8890	.8794	.9320	.9236	.9277	.9346	.9334	.9279	.9309	.9466	.9447
122	.8846	.8746	.9296	.9208	.9251	.9322	.9311	.9253	.9285	.9447	.9427
124	.8801	.8698	.9272	.9180	.9224	.9299	.9287	.9226	.9260	.9429	.9408
126	.8756	.8649	.9247	.9152	.9198	.9276	.9263	.9200	.9235	.9410	.9388
128	.8710	.8599	.9222	.9124	.9171	.9252	.9239	.9173	.9210	.9392	.9369
130	.8663	.8549	.9197	.9095	.9144	.9229	.9215	.9146	.9185	.9373	.9349
132	.8616	.8499	.9173	.9066	.9117	.9205	.9191	.9119	.9159	.9354	.9330
134	.8568	.8447	.9147	.9037	.9090	.9181	.9167	.9092	.9134	.9335	.9310
136	.8519	.8395	.9122	.9008	.9062	.9157	.9143	.9064	.9108	.9316	.9290
138	.8470	.8342	.9096	.8978	.9035	.9133	.9118	.9037	.9082	.9297	.9270
140	.8419	.8289	.9070	.8949	.9007	.9109	.9092	.9009	.9056	.9278	.9250

*Propene also known as propylene; butene also known as butylene.